OMB Clearance No. 2700-0087

National Aeronautics and Space Administration Headquarters
Exploration Systems Mission Directorate
Washington, DC 20546

Research Opportunities Soliciting Ground-Based Studies for Radiation Biology and Radiation Shielding Materials

New
NASA Research Announcement
NNH04ZUU005N

Catalog of Federal Domestic Assistance (CFDA) Number: 00.000

NRA Issued: August 20, 2004
Notices of Intent Due: September 20, 2004
Proposals Due: November 19, 2004

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Research Opportunities Soliciting Ground-Based Studies for Radiation Biology and Radiation Shielding Materials

I. Funding Opportunity Description

A. Summary

The National Aeronautics and Space Administration (NASA) Vision is:

To improve life here,
To extend life to there,
To find life beyond.

On January 14, 2004, the President of the United States announced a new vision for NASA to:

- implement a sustained and affordable human and robotic program to explore the solar system and beyond;
- extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;
- develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and
- promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.

The vision affirms the nation's commitment to space exploration and provides a clear direction for the civil space program. The activities carried out to implement this vision will be paced by experience, technology readiness (derived from scientific knowledge), and affordability. Implementation involves key missions, including Moon and Mars exploration.

This National Aeronautics and Space Administration (NASA) Research Announcement (NRA) solicits proposals for ground-based research in space radiation biology and space radiation shielding materials in support of the NASA vision. NASA will provide beams of high-energy heavy nuclei produced at the NASA Space Radiation Laboratory (NSRL) and the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory (BNL) for this research. These beams simulate the high-energy, high-charge (HZE) components of galactic cosmic rays that constitute the most biologically significant component of space radiation.

This NRA does not request proposals for space flight. Proposals that require space flight resources, including pre- and post-flight astronaut subjects, will be returned to the proposer without being reviewed. It is important that the proposer read all instructions in this NRA carefully, as many of the programmatic emphases are different from those appearing in previous NRAs.

To be responsive to this research solicitation, proposed studies should be hypothesis driven and lead to new knowledge within accepted scientific standards. Purely phenomenological approaches with no significant mechanistic basis or likely gain in scientific knowledge are not acceptable. Where appropriate, proposals should take into account the impact of gender, age, nutrition, stress, genetic predisposition, or sensitivity to other factors of importance.

Investigators are encouraged to review summaries of the research currently funded in this program by accessing the NASA Office of Biological and Physical Research (OBPR) Tasks and Bibliography (OBPR Task Book) at http://research.hq.nasa.gov/code_u/code_u.cfm. In order to achieve programmatic balance, specific topics that are currently well represented in our portfolio will be de-emphasized.

B. Background Information

1. Space Radiation Concepts

The following background information is intended to serve as an introduction to concepts essential for an understanding of space radiation research for scientists working in rapidly developing areas of life sciences or materials sciences not necessarily associated with the study of radiation. It is also intended to serve as an overview to scientists familiar with the use of conventional sources of terrestrial radiation who are interested in extending cutting edge radiation-related research to the problems of space radiation. Further details may be found in the list of references. NASA scientists are available to assist investigators wishing to enter this field of research and all investigators considering a response to this solicitation are encouraged to request more information. Experienced space radiation investigators may wish to skip this section.

The components of space radiation of greatest biological significance are the highly-charged, energetic heavy ions, also known as HZE particles, present in Galactic Cosmic Rays (GCR). The biological effects of radiation are caused by chemical reactions initiated by energy deposition in cells and tissues. These reactions modify the division processes by which cells reproduce as well as other cell functions required for healthy living organisms. Cells have the ability to repair themselves; when that repair is successful, the tissues and organisms return to their normal state. When the repair is not successful, cells may die. If a sufficiently large number of cells is killed, tissue integrity and function may be impaired, as occurs in acute radiation effects. Repair may be successful from the point of view of cell survival, but may contain latent errors that only manifest in subsequent generations of dividing cells. Radiation can also modify signal transduction and cell surveillance pathways in an adverse manner. These errors may also alter the sensitivity of cells to further insults or their ability to undergo normal cell division. Eventually radiation damage, in conjunction with other stresses, may further alter the cells or their interaction with surrounding tissues, as is assumed to occur during the induction of cancer, leading to delayed health effects.

For the particles composing space radiation, energy deposition is highly localized along the trajectory of each particle. This high rate of energy deposition per unit length of trajectory is the Linear Energy Transfer or LET; the unit generally used in radiobiology is the kilo-electron volt per micrometer, or keV/µm. The LET of charged particles changes as a function of the particle velocity or kinetic energy. As the velocity (or the energy) of a particle increases, the LET decreases to a minimum near a velocity of approximately 90% of the speed of light; at higher energies the LET increases very slowly. High-energy charged particles lose energy when they traverse any material. As they slow down, the LET increases to a maximum and then very rapidly decreases to zero. The low-energy maximum in LET occurs very close to the point where the charged particle loses its remaining energy and stops.

GCR particles of average energy can penetrate a substantial thickness of materials, on the order of 10's to 100's of centimeters of aluminum. If they suffer nuclear interactions, the lighter secondary products will lose energy at a lower rate, and therefore will be able to penetrate even further. For this reason, it is not possible to provide sufficient material to fully absorb all types of radiation in space. In addition, the biological effectiveness of radiation will change as a function of depth of penetration because the composition of the particles changes and because the LET of each particle changes as it loses energy and slows down inside the material.

Historically, the majority of radiobiological studies have been conducted using x-rays, which have become the standard of comparison and have a very low LET. Higher-LET particles generally require a lower dose than x-rays to induce a given observable biological effect. The quantity used to describe this is the relative biological effectiveness (RBE), which is equal to the ratio of the (generally higher) x-ray dose to the (generally lower) particle dose resulting in the same endpoint. For a multitude of radiation endpoints, the RBE varies significantly as a function of LET. The RBE peaks in the neighborhood of approximately 100 keV/µm, reflecting the geometry of sensitive targets within the cell. However, above this peak, the effectiveness for most endpoints again decreases due to the fact that further energy deposition in the damaged sites is wasted once a particular endpoint has been achieved.

The characterization of radiation quality in terms of RBE is widely used to describe biological response to radiation and is also the basis for the regulatory approach that specifies Quality Factors patterned after the LET dependence of RBE. Nevertheless, it is limited to biological endpoints for which a significant response to x-rays can be obtained. When this is not the case, the ensuing very large values of RBE ("infinite RBE") may be due to the lack of efficacy of x-rays rather than a particularly effective aspect of the high-LET radiation. The mechanisms and biological effects associated high-LET radiation also may be different from those attributable to x-rays for the same, or similar, macroscopic endpoints. For that reason, the description of radiation action is not complete without an understanding of the processes leading to an observed result.

At the present time, protection against the deleterious health effects of radiation is mainly achieved by limiting access to high radiation environments, controlling the duration of radiation exposure, and using materials to absorb radiation or degrade its energy. Materials with the smallest mean atomic mass are usually the most efficient shields for the GCR. Except for physical properties and safety considerations, hydrogen would be the best shield. The reasons for this are not immediately apparent. The absorbed dose from space radiation is delivered by many different kinds of particles incident on structures in space at a wide range of incident energies. The composition of the radiation field changes as particles lose energy and suffer nuclear interactions while traversing structural materials, instruments, and the bodies of crewmembers. Both the energy loss and the changes in particle fluence are related to the number of atoms per unit mass (in units such as grams) in the traversed material, which, in turn, is proportional to Avogadro's number divided by the atomic mass, A, for each element of the material.

The energy loss by ionization of a single component of shielding material with atomic number Z is proportional to the number of electrons per atom and thus proportional to Z/A. However, the energy lost per gram of material and per incident fluence (e.g., in units of particles per cm^2), the "mass stopping power," is also inversely proportional to the density, ḍ (e.g., in g/cm^3), of the material, so that the energy lost by one incident particle per cm^2 per unit mass is proportional to Z/dA.

The number of nuclear interactions per unit mass and per unit incident fluence is proportional to σ/A, where σ is the total nuclear reaction cross section. To a first approximation, σ is proportional to $A^{2/3}$, so that the nuclear transmission is proportional to $1/A^{1/3}$. The ratio of electronic stopping power to nuclear interaction transmission is thus proportional to $Z/dA^{2/3}$.

Materials with small atomic mass have the highest number of electrons per nucleon (e.g., Z/A is 1 for hydrogen, 0.5 for carbon, but 0.48 for aluminum, 0.46 for iron, and 0.40 for lead). However, light mass materials have smaller nuclei and therefore more of them can fit into a given mass, so that there can be more nuclear interactions. Furthermore, the ratio of ionization energy loss to nuclear interactions is also dependent on the material density. For liquid hydrogen ($d=0.07\ g/cm^3$), the ratio is ~14, whereas for aluminum ($d=2.7\ g/cm^3$) the ratio is only 0.5, and for lead ($d=11.3\ g/cm^3$) the ratio is 0.2.

It is clear from these considerations that a hypothetical shield consisting only of electrons, and thick enough to ensure that a particle loses all its energy inside it (a thickness referred to as the "range" of the particle) would provide ideal shielding characteristics. A close second choice would be a hypothetical shield made of hydrogen, which has the highest ratio of electrons to nuclei per atom. However, while the range of an energetic iron nucleus with an energy of 1 GeV/nucleon (near the peak of the GCR energy spectrum) is approximately 30 cm in water (approximately 10 cm in aluminum), the range of a proton is 12 times greater and a shield intended to stop all particles up to iron would have to be equivalent to 300 cm of water or 100 cm of aluminum. Such thickness is not practical, and nuclear reactions will always be a component of shielded radiation fields.

Slowing down incident GCR particles using materials with a preponderance of energy loss due to ionization and a minimum probability of nuclear interactions is not always an optimal strategy. Nuclei such as carbon and oxygen incident at high energy and have low LET that is well beneath the peak value of RBE. When they lose energy in a shielding material (without suffering nuclear interactions), their LET increases. As a consequence, their RBE also increases instead of decreasing, so that they become more hazardous rather than less hazardous. On the other hand, the LET of incident, high-energy heavier nuclei (such as iron) is close to the 100 keV/μm corresponding to the peak RBE. Losing energy and slowing down further increases their LET beyond the peak, yet they become no more hazardous despite their higher LET.

Conversely, nuclear interactions that change a penetrating GCR nucleus into lighter nuclei, e.g., nuclear interactions that fragment silicon into carbon and helium-4 (alpha particles), result in particles of lower RBE, the desired outcome. On the other hand, the fragmentation of high-LET iron into lower-LET chromium or silicon fragments would change the contribution to the radiation field from less hazardous particles, beyond the RBE peak, to more hazardous particles with an LET at or before the peak.

The character of these interactions is also important. Lighter nuclei have fewer neutrons to release and some nuclei, e.g., carbon, can break into three helium nuclei without releasing any neutrons. In tissue, the release of three relatively short-range and densely ionizing helium atoms can lead to much more biological damage than the release of fast, penetrating neutrons. However, neutrons produced within spacecraft shielding materials are of greater concern because of their penetrating nature. For very thick shields, lighter nuclei are also more effective in shielding against the built up neutrons. For these and related reasons, detailed knowledge of the actual composition of the radiation fields (and of the biological consequences of exposure to them) is required to evaluate the net effect of shielding materials.

2. Critical Path Roadmap

In order to identify and make publicly known the biomedical and health risks of space flight and the research questions that must be answered to reduce those risks, NASA has developed the Bioastronautics Critical Path Roadmap (BCPR). The BCPR is an interdisciplinary tool to assess, understand, mitigate, and manage the risks to humans that are associated with long-term exposure to the space environment. It assumes an overarching strategy that integrates requirements, risks, risk factors, critical questions, tasks, deliverables, and risk mitigation with the intent of directing biomedical research in support of human space flight, especially human missions of exploration. The BCPR is based in part on recommendations from internal NASA experts, NSBRI scientists, advisory committees representing the United States science community, task forces, and published reports such as the National Research Council (NRC) Space Studies Board's "A Strategy for Research in Space Biology and Medicine in the New Century;" the Aerospace Medical Advisory Committee; the NASA Task Force on Countermeasures; the International Space Life Sciences Working Groups publications on Radiation, Bone, Muscle, Cardiovascular, Human Factors, and Neuroscience Workshops; and the NASA Medical Policy Board Document.

The ultimate goal of the BCPR is to protect the health and safety of space flight crews by allowing NASA and the community of scientists to better define and focus the research that is required for development and validation of operational health care "deliverables" for the prevention, treatment, and rehabilitation of space flight changes and of appropriate habitation and medical care systems.

The BCPR is not a “critical path” analysis in the strict engineering sense. The BCPR will evolve to accommodate new information and technology development and will enable a formal critical path analysis in the future.

The current BCPR identifies 50 risks and over 400 enabling questions. The BCPR, at http://research.hq.nasa.gov/code_u/bcpr/index.cfm, should be reviewed by potential investigators**.**

The proposer must examine and understand the BCPR and specify in their proposal the rationale and evidence underlying which risks and critical questions their proposed research will address. The sample form (Form B) can be found attached to this NRA or at http://research.hq.nasa.gov/code_u/nra/current/ NNH04ZUU005N /index.html. **NASA will perform a similar assessment to understand how the proposed research addresses the BCPR risks and critical questions. Proposals that do not identify what BCPR risks and questions are being addressed by the research will be returned to the proposer without review.**

There are currently five categories of radiation risks in the Critical Path Roadmap. Each radiation risk has an associated set of enabling questions. For radiation, for each of the risk areas, these are:

Carcinogenesis

What are the probabilities for increased carcinogenesis from space radiation as a function of NASA’s operational parameters (age at exposure, age, latency, gender, tissue, mission, radiation quality, dose rate, and exposure protraction)?

How can tissue-specific probabilities for increased carcinogenesis risk from space radiation be best evaluated and what molecular, genetic, epigenetic, and abscopal (effect that irradiation of a tissue has on remote non-irradiated tissue), or other factors contribute to the tissue specificity of carcinogenic risk?

How can the individual’s sensitivity to radiation carcinogenesis be estimated?

How can effective biomarkers of carcinogenic risk from space radiation be developed and validated?

What are the most effective biomedical or dietary countermeasures to mitigate cancer risks? By what mechanisms are the countermeasures expected to work and do they have the same efficiency for low- and high-LET radiation?

How can animal models (including transgenics) of carcinogenesis be developed to improve estimates of cancers from space radiation and what longitudinal studies are needed?

What improvements can be made to quantitative procedures or theoretical models in order to extrapolate molecular, cellular, or animal results to determine the risks of specific cancers in astronauts? How can human epidemiology data best support these procedures or models?

Are there significant combined effects from other space flight factors (microgravity, stress, altered circadian rhythms, changes in immune responses, etc.) that modify the carcinogenic risk from space radiation?

What are the probabilities that space radiation will produce damage at specific sites on DNA, including clustered DNA damage?

What mechanisms modulate radiation damage at the molecular level (e.g., repair, errors in repair, signal transduction, gene amplification, bystander effects, tissue microenvironment, etc.) that significantly impact the risk of cancers and how can the understanding of mechanisms be used to predict carcinogenic risks from space radiation?

What space validation experiments could improve estimates of carcinogenic risks for long-term deep-space missions?

What are the most effective shielding approaches to mitigate cancer risks?

What new materials or active shielding methods can be used for reducing space radiation cancer risks?

Acute and Late Central Nervous System (CNS) Risks

Is there a significant probability that space radiation would lead to immediate or acute functional changes in the CNS due to a long-term space mission and, if so, what are the mechanisms of change?

Is there a significant probability that space radiation exposures would lead to long-term or late degenerative CNS risks? If so what are the mechanisms of change?

How does individual susceptibility, including hereditary pre-disposition (Alzheimer’s, Parkinson’s, apoE), and prior CNS injury (concussion or other) alter significant CNS risks?

What are the most effective biomedical or dietary countermeasures to mitigate CNS risks? By what mechanisms do the countermeasures work?

How can animal models of CNS risks, including altered motor and cognitive function, behavioral changes, and late degenerative risks be best used for estimating space radiation risks to astronauts?

Are there significant CNS risks from combined space radiation and other physiological or space flight factors (e.g., bone loss, microgravity, immune-endocrine systems, or other)?

What are the molecular, cellular, and tissue mechanisms of damage [DNA damage processing, oxidative damage, cell loss through apoptosis or necrosis, changes in the extra-cellular matrix, cytokine activation, inflammation, changes in plasticity, micro-lesion (clusters of damaged cells along heavy ion track, etc.] in the CNS?

What are the different roles of neural cell populations, including neuronal stem cells and their integrative mechanisms, in the morphological and functional consequences of space radiation exposure?

Are there biomarkers for detecting damage or susceptibility to/for radiation-induced CNS damage?

What quantitative procedures or theoretical models are needed to extrapolate molecular, cellular, or animal results to predict CNS risks in astronauts? How can human epidemiology data best support these procedures or models?

What are the most effective shielding approaches to mitigate CNS risks?

What space validation experiments could improve estimates of CNS risks for long-term deep-space missions?

Other Degenerative Tissue Risks

What are the probabilities for degenerative tissue risks from protons and HZE ions as a function of NASA's operational parameters (age at exposure, age and time after exposure, gender, tissue, mission, radiation quality, dose rate)?

What are the mechanisms of degenerative tissues risks in the heart, circulatory, endocrine, digestive, lens and other tissue systems?

How can the latency period for degenerative tissue risks, including sub-clinical diseases, following space radiation exposures be estimated?

What are the most effective biomedical or dietary countermeasures to degenerative tissue risks? By what mechanisms do the countermeasures work?

What quantitative procedures or theoretical models are needed to extrapolate molecular, cellular, or animal results to predict degenerative tissue risks in astronauts? How can human epidemiology data best support these procedures or models?

Heredity, Fertility and Sterility Risks

What are the risks of hereditary, fertility, or sterility effects as a result of exposure to space radiation?

Is there a transmissible risk for neurodegenerative or other non-cancer/non-CNS diseases to the offspring of those exposed to radiation?

Acute Radiation Syndromes

How can predictions of acute space radiation events be improved?

Are there synergistic effects arising from other space flight factors (microgravity, stress, immune status, bone loss, damage to intestinal cells reducing their ability to absorb medication? etc.) that modify acute risks from space radiation including modifying thresholds for such effects?

What are the molecular, cellular, and tissue mechanisms of acute radiation damage (DNA damage processing, oxidative damage, cell loss through apoptosis or necrosis, cytokine activation, etc.)?

Does protracted exposure to space radiation modify acute doses from SPEs in relationship to acute radiation syndromes?

What are the most effective biomedical or dietary countermeasures to mitigate acute radiation risks? By what mechanisms do the countermeasures work?

What quantitative procedures or theoretical models are needed to extrapolate molecular, cellular, or animal results to predict acute radiation risks in astronauts? How can human epidemiology data best support these procedures or models?

What are the most effective shielding approaches to mitigate acute radiation risks?

C. Solicitation Focus

1. Introduction

The goal of the NASA Space Radiation Research Program is to assure that we can safely live and work in the space radiation environment, anywhere, any time. Space radiation is distinct from terrestrial forms of radiation, being comprised of high-energy protons and heavy ions and their secondaries produced in shielding and tissue. Because there are no human epidemiological data for these radiation types, risk estimation must be derived from mechanistic understanding based on radiation physics, and on molecular, cellular, and tissue radiation biology related to cancer and other risks of concern to NASA. The core values of the space radiation program demand that **all recommendations and requirements shall be developed only on the basis of research conducted according to the highest standards of scientific inquiry, addressing clearly stated, falsifiable hypotheses and using the most appropriate methods available.** While flight studies are recognized as being an essential component in the validation of radiation risk predictions, the scientific evidence is expected to be acquired on the ground, by irradiations simulating exposure to components of space radiation, the most significant of which are the high energy charged particles delivered by accelerator beams.

Research to be supported will seek to reduce the uncertainties in risk predictions, including cancer, degenerative tissue damage (e.g., the central nervous system (CNS) and cataracts), hereditary risks, fertility and sterility risks, and acute risks, and lead to the development of effective shielding or biological countermeasures to these risks.

This section defines the research program and elements encompassed by this Announcement, describes the specific areas of ground-based research that proposals should address, and describes the specific emphases that are acceptable for submission in response to this Announcement. **This NRA does not request proposals for space flight research.** It is important that the prospective investigator read the relevant section(s) carefully, as some of the programmatic emphases are different from those appearing in previous Division Announcements. In addition, this NRA includes guidelines for preparing and submitting proposals and defines the administrative policies governing the program and investigators.

2. Radiation Sources

Research proposals are expected to utilize beams of charged particles available at Brookhaven National Laboratory (BNL), the Galactic Cosmic Ray (GCR) environment available to Radiation Shielding investigators on the Deep Space Test Bed (DSTB), or to address experimental data obtained with such beams in ways leading to significant predictions that can be tested in future experiments. In FY2005, the beams most likely to be available are those from the NASA Space Radiation Laboratory (NSRL). Alternate Gradient Synchrotron (AGS) beams are available, and experiments with scientific justification for the use of their higher energies are also solicited. NASA intends to operate these facilities for 1200 hours per year if funds are available. Selection of beam species and beam energies for experimental running periods will be made by program managers in consultation with scientists proposing experiments for these beams. Investigators selected for funding will need to meet BNL requirements for experiment scheduling in order to gain access to beams and irradiation facilities. Proposals for utilization of the DSTB prior to January 2006 cannot be supported. Researchers are encouraged to consult Section E, Facilities, for a more detailed description of the test opportunities afforded by the DSTB.

NASA negotiates beam delivery directly with BNL, and investigators proposing to use the BNL irradiation facilities should not include the cost of beam time in their budgets. However, investigators should include the cost of carrying out the experiments, including travel to these facilities, and provide an estimate of the hours of beam time. Investigators wishing to utilize other facilities must provide a detailed justification for their use and must include certification that use of those facilities will be at no cost to NASA.

3. Current Research Areas

While the Critical Path Roadmap describes the overall research aims for reducing the human health risks from exposure to space radiation, the current NASA Space Radiation program is organized into the following research areas:

- Radiation Measurement Technologies (including Biodosimeters, Detector Systems, Embedded Sensor Technologies and Extreme Environment Dosimeters),

- Shielding Solutions (including Radiation Models, Physical Measurements, Materials Recommendations, Non-Material Shielding Concepts, and Insertion Technologies),

- Risk Assessment & Projection (including Integrated Risk(s) Projection, Cellular & Molecular Processes, Biological Mechanisms & Consequences, and Biomarkers of Individual Risk),

- Biological Countermeasures (including Pharmacological and Genetic Prescriptions and Nutritional Supplements); and,

- Crosscutting Flight and Planetary Missions (including spaceflight missions beyond Low Earth Orbit).

Physical Sciences research areas emphasize studies of the basic, as well as applied, physical aspects of the interaction of high energy charged (HZE) particles with matter, and the design, fabrication, and testing of multifunctional radiation shielding materials. Experimental data are available from the work of ongoing NASA-supported measurements of nuclear interaction cross sections and yields via the FY03 selected Cross Section Measurements Consortium, and complementary radiation transport codes are being developed by NASA-supported investigators via the FY03 selected Radiation Transport Codes Consortium. The compilation of data into easily accessible formats and the development of three-dimensional standardized radiation transport codes for use by designers of mission architectures are priorities for the Consortia. There are multiple transport code and cross section measurement methodologies currently being pursued by the consortia and NASA has assigned a lower strategic value to new proposals in these areas. However, novel research concepts that significantly accelerate NASA's development of an accurate modeling tool of the radiation transport phenomenon are solicited. NASA encourages researchers to utilize the facilities and capabilities of these previously selected consortia. Researchers needing cross-section/yield measurements or radiation transport calculations should contact the appropriate Consortium. Consortium points of contact are listed in Section VI, "Other Technical Information."

Radiobiology research areas emphasize the application of mechanistic understanding to mammalian models to achieve significant reductions in the uncertainties in risk projections in humans for cancer, degenerative tissue effects including damage to the CNS and other health effects caused by space radiation, or to develop effective biological countermeasures to these risks. Biological effects of importance include DNA damage processing, signal transduction, cell cycle controls, cellular differentiation, bystander effects, genomic instability, genetic sensitivity or resistance, signal transduction, and persistent oxidative damage. This research is intended to develop approaches to understand the effects of protons and heavy ions as modifiers of these processes. The use of such understanding to develop new transgenic mouse or tissue models improving our ability to extrapolate estimates of cancer and other risks to humans is of high priority. Finally, the development of methods for accurate, quantitative risk prediction is encouraged, both experimentally in terms of biological predictors of individual radiation risk and theoretically using appropriate models for quantitative individual risk assessments.

It is recognized that progress in these areas will depend on progress in the understanding of fundamental biological processes. These include: DNA structural and functional changes caused by radiation, such as mutations and DNA recombination and repair; basic metabolic controls important in biology and known to be modulated by radiation; the cell cycle, especially in relation to cellular repair mechanisms and programmed cell death; mechanisms of tissue and organ response to radiation including signal transduction; and “bystander” effects and genomic instability. The knowledge gained should have plausible links to Bioastronautics studies directed at estimating risk to astronaut health and ameliorating negative health effects of space flight. Proposals must include a description of these links. To an appropriate extent, these studies should also lead to quantitative predictions about the interaction of hypergravity or simulated microgravity on these mechanisms that can be subjected to experimental validation.

Currently funded studies are concentrated on cancer-related radiobiology, physical measurements of particle cross sections and yields, and some investigations of CNS effects. While research in these areas will continue to be supported, this Announcement emphasizes additional areas of research, not currently covered, although compelling proposals offering the likelihood of significant advances in current research will also be considered. Investigators are encouraged to review summaries of the research currently funded in this program by accessing the NASA Office of Biological and Physical Research (OBPR) Tasks and Bibliography (OBPR Task Book) at http://research.hq.nasa.gov/taskbook.cfm.

Those proposing in response to this NRA are encouraged to take advantage of the services afforded by the Space Radiation Shielding Program (SRSP) at Marshall Space Flight Center (MSFC). Please reference http://www.radiationshielding.nasa.gov/ for additional information.

Studies may include animals (including humans), plants, tissues, or cells. Researchers should use the species most appropriate for their research and are encouraged to take advantage of functionally characterized transgenic and mutant species as well as comparative biology approaches that enhance the research scope. Note that as part of the proposal submission process assurance of compliance with applicable federal regulations regarding human subjects or animal care and use is required (see the “Special Matters” instructions in Appendix B).

4. Research Emphases

In view of the uncertainty in future availability of AGS beams (energies above 600 MeV/nucleon), studies requiring such beams will be given preference in this solicitation. The following high-priority research topics are emphasized for FY2005:

a) *Risk Assessment and Projection*

- **Biological Mechanisms and Consequences** represent one of the highest priority areas of NASA radiation research. A substantial effort directed toward carcinogenesis and CNS effects is underway. This solicitation seeks investigation of **Non-Cancer or Degenerative Tissue Risks** as an important complement to ongoing investigations. Recent epidemiology studies have identified a significant non-cancer/non-CNS risk in cohorts exposed to low-LET radiation. These risks include increased morbidity and mortality due to circulatory and heart diseases. This topic addresses the identification of the biological mechanisms and processes involved, and the development of experimental models to estimate the risk from protons and HZE ions, including the basis for describing dose, dose-rate, and latency dependencies.

- Investigations likely to provide significant insights into **Cellular and Molecular Processes** at the root of these mechanisms are also solicited, to the extent that their relationship to the mechanisms and consequences can be demonstrated. Some end-points that may be relevant include cell signaling, DNA damage repair through the homologous and non-homologous pathways, or combined DSB and base-damage repair pathways, gene expression, mutation, cytokine/hormone release, proteomics assays (in blood), behavior/cognitive effects, and stem cell turnover.

- Methods to measure relevant radiobiological endpoints at low fluences of HZE particles are of particular interest if they offer a high likelihood of prospective adaptation for use in spaceflight.

- Approaches likely to lead to significantly improved understanding of genetic mechanisms underlying radiation responses (e.g., sensitivity, susceptibility, resistance) for all BCRP risks, including the extrapolation of knowledge gained from cellular, tissue, or animal models to the prediction of human risks may be supported to the extent that they are likely to play a leading role in achieving NASA goals in uncertainty reduction.

b) Shielding Solutions

- **Novel Shielding and Multi-Functional Materials:** NASA anticipates that the mass of the radiation shielding required for manned exploration missions will be a major design driver. Wishing to minimize mission mass, NASA is supporting research to develop new multi-functional materials that provide effective radiation shielding while being suitable for the fabrication of system components needed for these missions. Polyethylene (PE), due to its high hydrogen content and relative weight, has been shown to be an effective shielding material against galactic cosmic rays and solar energetic particles. This NRA solicits proposals that address the design, synthesis, processing, fabrication, and testing (including accelerator-based testing) of multi-functional materials. These materials must be suitable for fabrication of one or more components of crewed space vehicles, rovers, habitats, or spacesuits. Use of these materials must make a significant contribution to reducing the mass of the system for which they are intended. Deliverables will be specifications for multifunctional materials with radiation shielding effectiveness comparable or superior to that of PE and with materials properties and extreme environmental durability that make them suitable for use in one or more components for crewed deep space missions. Proposals addressing questions associated with the cost, processing, efficiency, safety, etc. associated with the manufacturing of known or potential shielding materials are also sought by this NRA. Development of methods to measure (non-radiation related) materials properties that offer a likely prospect for adaptation to spaceflight is also encouraged.

- **Radiation Shielding Effectiveness:** NASA recognizes the need for computational tools to assess the radiation shielding effectiveness of materials. The more basic questions pertaining to radiation shielding effectiveness assessment, e.g., development of simulation and radiation transport methodologies/codes, calculation/measurement of nuclear cross sections, etc., are being addressed, in part, by currently funded investigations. However, proposals offering a compelling likelihood of resulting in substantial or significantly accelerated progress, especially in the measurement of physical quantities (cross sections and yields of nuclear reaction products produced in relevant material samples) will be considered. In particular, proposals for the analysis of relevant existing cross section or yield measurements, and new measurements that will test the event generators used in transport codes that employ Monte Carlo techniques, new cross section and yield measurements of neutron emission, transverse and/or longitudinal momenta for a variety of projectile and target combinations are of interest.

D. Ground Facilities Description

1. Ground-Based Radiation Accelerator Facilities

NASA has signed agreements with Loma Linda University (LLU) Medical Center related to the use of proton beams, and with Brookhaven National Laboratory (BNL) for the use of heavy ion beams at the Alternating Gradient Synchrotron (AGS). **This NRA solicits proposals for research at BNL**; information about LLU is provided because proton irradiations have constituted an important component of the broader research program, and investigators may have reason to seek access to proton beams for preliminary results or comparison with existing data. Delivery of beam time at BNL is directly funded by a contract between NASA and Brookhaven. Use of the Brookhaven facilities requires a separate proposal (after selection by NASA), which is reviewed by a laboratory-appointed panel and is scheduled in accordance with available beam time and other laboratory resources. Once experiments are approved, they are required to satisfy the normal process of preparation, which includes familiarization with rules and policies (safety being the paramount consideration among these) and registration with the laboratory as a guest scientist.

The NASA Space Radiation Laboratory (NSRL) became operational in June 2003. The NSRL is an accelerator facility that provides ions from protons to gold in the energy range of 40-3000 MeV/amu, using beams from the AGS Booster synchrotron placed between the Van de Graaff injectors and the higher energy AGS. The NSRL is a joint effort of the collider-accelerator department, providing accelerated ion beams; the BNL Biology department, providing experimental area support; and the Medical department, which provides animal care facilities and cell laboratories. The experimental facilities consist of a well-shielded irradiation area and a support building containing ready-rooms, laboratories, and offices. Other existing on-site facilities, such as the Medical Department’s extensive animal handling installations, may also be utilized. Dosimetry and local access control will be provided through a local facility control room.

The Brookhaven AGS Booster is an ideal source for the NSRL due to the good overlap between the available ion masses and energies with those encountered in space. A variety of high-Z-energy (HZE) particles are available with energies ranging from a maximum of 3000 MeV for protons, 1.3 GeV/amu for the medium mass ions, to approximately 1.1 GeV/amu for iron, and approximately 300 MeV/amu for gold, to a minimum of less than 100 MeV/amu for all beams. Beams of 290 MeV/amu carbon, 1200 MeV/A titanium, and 1000 MeV/amu iron have been accelerated. Heavy ions originate in the Brookhaven MP-6 tandem accelerator and are transported to the Booster synchrotron for acceleration to the required energies. Concurrent operation of the Booster for space radiation research and other kinds of research applications is achieved by utilizing independent tandem injectors. At the Booster a new slow-extraction system has been implemented and a new beam line and tunnel enclosure have been built to transport the extracted beam to the experimental facility. Uniform beam intensities have been measured over rectangular areas ranging in size from about 1 cm to about 20 cm with uniformity of ±5%.

Some experiments employing fractionation schedules consisting of one irradiation per day for several days, and mixed-fields of two beams of different ions delivered within a small time (few minutes to 1-hour) of each other have been successfully conducted at NSRL and similar experiments can be proposed for future investigations. Expansion of multiparticle irradiation capability and for solar particle event simulation (with proton energies up to 3,000 MeV) is intended to be available at NSRL in the near future.

The AGS machine at BNL is a U.S. Department of Energy (DOE) facility that is funded by the DOE primarily for research in high-energy particle and nuclear physics. Brookhaven is allowed by the DOE to provide additional AGS beam time to other scientific users of the machine, as long as the sponsor of such proposed work provides operating funds. A 10-ft long optical bench for sample exposures is available in the cave, as well as beam handling, sample changing, and dosimetry instrumentation. The biological experiment station contains one area for cell culture equipped with a laminar flow hood and incubator, one short-term animal holding facility, and one area for physics/run-control use. Iron (^{56}Fe) beams at 600 MeV/amu and at 1 GeV/amu, as well as ^{28}Si and ^{79}Au, have been used for experiments to date; investigators who need to use other beams or energies should contact the Brookhaven liaison scientists listed below. Normally, circular beam spots are provided, with diameters up to 10 cm and center-to-edge uniformity between 10% and 20% (depending on dose rate—high dose rate beams are less uniform than low-dose rate beams). Dose rates have been measured up to 11 Gy/min. A physics and dosimetry group is available for investigators requiring their assistance.

User facilities have been developed at Brookhaven for radiation biology research, including cell cultures and small animals. These include the shielding caves containing the beam and the experiment station. In addition, laboratory space and access to animal facilities accredited by the Association for Assessment and Accreditation of Laboratory Animal Care are available in the Medical Department, subject to standard use charges. Brookhaven also has on-site housing accommodation for users (dormitory and apartment-style units).

NASA will assist investigators in planning and conducting materials experiments at the NASA Space Radiation Laboratory (NSRL). Proposals that include utilization of the NSRL should include a list of desired ions and energies, and the estimated beam time. It is anticipated that there will be several opportunities each calendar year for investigator beam time. However, beam times are subject to change and contingent upon availability of funding.

Further detailed information on BNL is available at: http://www.bnl.gov/bnlweb/userindex.html. For further information regarding Brookhaven National Laboratory, contact Dr. Marcelo Vazquez (e-mail: vazquez@bnl.gov), Dr. Betsy Sutherland (e-mail: betsy@image.bio.bnl.gov), or Dr. Phil Pile (e-mail: pile@bnldag.ags.bnl.gov).

Consult this research announcement for instructions on how to incorporate the use of these facilities into a proposal. These instructions **must** be followed in order to access the facilities.

2. Materials Testing Facilities at NASA Marshall Space Flight Center (MSFC)

The NASA Marshall Space Flight Center has a wide range of capabilities available to the radiation materials researcher. These capabilities include composite materials fabrication, mechanical and environmental testing, nondestructive testing, polymer thermal analysis and space and environmental effects testing. Points of Contact are listed for each facility and laboratory to provide the researcher with more detail of specific capabilities and/or to arrange for the provision of testing, fabrication, or analysis services.

a) *Composite Materials Fabrication*

A wide range of facilities is available for processing of polymers and fiber-reinforced polymer matrix composites. Housed within the National Center for Advanced Manufacturing facility at the Marshall Center, a wide range of equipment is also available for materials fabrication. This equipment includes two CMI automated fiber placement machines, an 18 x 20 ft. and a 9 x 12 ft. autoclave, and a range of presses and ovens. Filament winding capabilities include a polar and a helical winder. Full-service machine shops are available on-site on a contract basis for the fabrication of tooling and miscellaneous hardware. Other related services that are available include manufacturing process development, and adhesives and bonding process development.

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b) *Mechanical and Environmental Testing*

A full-service laboratory is available and dedicated to the performance of a wide range of materials testing and evaluations. A total of six mechanical test frames are available for mechanical property testing of materials up to 100K-lbs of load. The lab has the capability to perform mechanical property testing of materials at elevated temperatures, high heat rates and at cryogenic temperatures (LN2, -320ºF). A well-trained staff is available on a contract basis to prepare specimens, perform tests and to collect and reduce data. The staff has experience in performing a number of different tests, including tension, compression, flatwise tension, adhesive bond strength, and lap shear testing.

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c) *Non-Destructive Evaluation*

A number of different non-destructive test methods are available within Marshall's Non-Destructive Evaluation Group. These methods include ultrasonics, thermography, shearography, computed tomography, eddy current inspection, radiography, and acoustic emission testing. A staff of engineers, each with dedicated experience in one or more NDE methods, is available for consultation and materials testing and evaluation.

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d) *Thermal Analysis for Polymer Characterization*

The Thermal Analysis laboratory at MSFC is available for the characterization of thermal, physical and reactive behavior of materials as a function of temperature. Four different instruments are available in the lab to perform the following analyses: differential scanning calorimeter (DSC), thermomechanical analysis (TMA), thermogravimetric analysis (TGA), and dynamic mechanical analysis (DMA). Functions of this lab include material screening and selection, cure characterization of thermosetting polymers, determination of the glass transition temperature and crystalline melt temperature of thermoplastics, material compatibility studies and failure investigations. Low temperature testing may be performed down to –150ºC during

DSC, TMA, and DMA investigations. Additional capability includes the measurement of the coefficient of thermal expansion of materials. A dedicated technical support staff is available to support research in this area.

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e) *Space and Environmental Effects Testing*

http://mpm.msfc.nasa.gov/ED31/index.html
The engineers, physicists, and technicians of the SEE Team evaluate candidate materials by exposing them to laboratory simulations of the space environment, which are complemented by flight experiments whenever possible. The team's simulation capabilities include charged-particle radiation, ultraviolet (UV) radiation, atomic oxygen (AO), plasma, thermal vacuum, and hypervelocity particle impact. The team operates a unique facility for combined environmental effects (CEE) testing. Atomic oxygen, UV radiation, charged particles, plasma, and thermal vacuum may affect the optical, mechanical, and electrical properties of materials. The synergistic effects of these aspects of the space environment are still not completely understood and continue to be investigated. Data from these specialized test systems, combined with analytical results from material flight experiments, enable the SEE Team to determine optimum materials for use on spacecraft.

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f) *Micrometeor and Orbital Debris Testing*

Meteoroid and orbital debris impacts are a serious concern for spacecraft in orbit. More than 9,000 objects are being tracked, with millions more particles too small for radar or telescopes to track. These particles travel at hypervelocity speeds, with an average velocity of 10 km/s for orbital debris and up to 60 km/s for micrometeoroids. Micrometeoroids and space debris can puncture manned spacecraft, pit windows and telescope mirrors, and damage solar arrays and thermal radiators. In order to avoid collisions with space debris, spacecraft may be forced to use limited fuel supplies. To quantify the damage caused by debris particles or qualify debris protection systems, MSFC has the micro light gas gun (MLGG). The MLGG is capable of accelerating small particles (0.1–1 mm in diameter) to velocities of 3–9 km/s. The test chamber allows for target samples up to 20 by 20 cm. Projectile velocity is measured with each test using photodiodes attached to an oscilloscope.

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3. Materials Testing Facilities at NASA Langley Research Center (LaRC)

The NASA Langley Research Center's Advanced Materials and Processes Branch has a wide range of materials analysis and characterization laboratories available to the radiation shielding materials development researcher. Capabilities include molecular characterization, thermal analysis, molecular weight characterization, solution characterization, polymer melt rheology, polymer and composite mechanical testing, and electrical and electromechanical characterization. Additionally, a wide range of optical and electron microscopy methods are available for use as well as tools for image analysis.

a) Thermal Analysis

Thermal analysis and characterization capabilities include differential scanning calorimetry (DSC), thermal mechanical analysis (TMA), thermogravimetric analysis (TGA), differential thermal analysis (DTA), and dynamic mechanical analysis (DMA). Additional capability includes the measurement of the thermal conductivity of materials.

b) Molecular Characterization

A wide range of instrumentation and testing equipment are available at LaRC for characterization of materials on the molecular level. Test capabilities include Fourier Transform Infrared Spectroscopy (FTIR) in diffuse, transmission attenuated, and specular reflectance modes, UV-Visible-NIR Spectroscopy, Dispersive Raman Spectroscopy, NMR, MALDI-TOF Spectroscopy and HPLC Mass Spectroscopy.

c) Solution and Molecular Weight Characterization

Solution characterization may be performed including intrinsic viscosity measurements, High-Pressure Liquid Chromatography and Brookfield Viscosity. A number of test methods are available at LaRC for the determination of molecular weights. These include room temperature gel permeation and elevated temperature gel permeation chromatography, low-angle laser light scattering, and differential, membrane, and vapor phase osmometry.

d) *Rheology*

A range of rheometers and other instruments are available at LaRC for the study of the melt flow and viscoelastic behavior of polymeric materials. Langley's facilities include capillary, parallel plate, and rotary rheometers. Brabender twin-screw extruder is also available for polymer melt flow studies.

e) *Microscopy*

Numerous instruments are available at Langley for micrographic analysis. These include scanning tunneling, atomic force, and high-resolution scanning electron microscopy. Other capabilities include polarized light transmission microscopy as well as optical microscopy and image analysis tools.

f) *Mechanical Testing for Resins and Composites*

Mechanical property testing of composites and resins is available at Langley. A well-trained technical staff is capable of performing a number of property tests including fracture toughness, flexure, film tensile, short beam shear, tensile lap shear and individual fiber tensile and elongation testing.

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4. Deep Space Test-Bed Facility

NASA is presently developing a Deep Space Test-Bed (DSTB) Facility to conduct radiation-shielding tests in a realistic deep space radiation environment. Earth's magnetic field prevents the full energy spectrum of the Galactic Cosmic Rays (GCR) in interplanetary space from reaching the upper atmosphere except in the Polar Regions. The DSTB approach uses high altitude stratospheric balloons launched at high magnetic latitudes to access the full energy spectrum and composition of the GCRs. These balloons are capable of lifting 1200 kgs of apparatus to altitudes of 3.5millibars (3.5 grams/cm^2 of residual atmosphere). In the past decade such flights have been regularly conducted from Antarctica during the local summer. Flights are launched from McMurdo Station, Antarctica and make a complete circumnavigation of the continent in approximately 20 days providing significant exposure to GCR.

The DSTB is operated as a facility and consists of the gondola, integration laboratory, and support for ground and flight operations. The gondola is designed to carry multiple experiments on each flight. Standard instrumentation is provided by the facility to monitor the radiation environment. The facility also provides supporting subsystems including: solar arrays, power distribution, command and telemetry support, housekeeping, and the mechanical structure. Resources of power, mass, and telemetry are shared among the individual experiments. Present limitations of these shared resources are: 1200 kgs, 600 watts and 6 kbits/s telemetry rate. How these resources are allocated among the experiments will depend on the requirements of the individual experiments and the composition of the experiment complement. For example, if there are 10 experiments on a flight, the average resources available per experiment are 120 kgs, 60 watts and 600 bits/s telemetry. The final distribution of these resources will depend on the experiment complement chosen for each campaign.

The flow process for each DSTB flight includes selecting the individual experiments to form the experiment complement, configuring the DSTB gondola to accommodate the chosen experiments, integration of the experiments on to the gondola, compatibility testing, field operations, and return of the payload and data to the investigators. One full cycle will span approximately 18 months. Flights are planned on an annual basis and will follow the process flow outlined above.

Additional information relating to the DSTB facility can be found at the website: http://sd.msfc.nasa.gov/cosmicray/dstb/dstb.htm.. For technical information relating to the DSTB Facility please contact Mark J. Christl at (256) 961-7739 or mark.j.christl@nasa.gov..

5. Other Technical Information

For additional information about NASA and its mission and goals, please visit http://www.nasa.gov/. For additional information about the Office of Biological and Physical Research, please visit http://spaceresearch.nasa.gov/.

For information about the shielding consortia contact:

Transport Codes Consortium:
Lawrence W. Townsend, Ph.D.
Robert M. Condra, Professor of Nuclear Engineering
Department of Nuclear Engineering
The University of Tennessee
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Cross Section Measurements Consortium:
Jack Miller
Lawrence Berkeley National Laboratory
MS 74-197
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E. Education and Public Outreach

Exploration Systems Mission Directorate (ESMD) programs represent an opportunity for NASA to enhance and broaden public knowledge, understanding, and appreciation of biological and biomedical research, and the value of this research in space environments. Individuals participating in NASA's ESMD programs have a responsibility to foster the development of a scientifically informed public. Therefore, all participants in this NRA are strongly encouraged to promote general scientific literacy and public understanding of biological and biomedical sciences, space environments, and ESMD programs through formal and informal education opportunities.

ESMD envisions that the selected proposals will be structured and operated in a manner that supports the nation's educational initiatives and goals (including support of historically black colleges and universities and other minority universities), and in particular the need to promote scientific and technical education at all levels. ESMD envisions that the selected proposals will support the goals for public awareness and outreach to the general public. The selected principal investigators are invited to participate in ESMD-funded educational programs.
The successful research project represents an opportunity for NASA to enhance and broaden the public's understanding and appreciation of the value of ESMD research in the context of NASA's mission. Therefore, all investigators are strongly encouraged to promote general scientific literacy and public understanding of ESMD research through formal and/or informal education opportunities. If appropriate, proposals should include a clear and concise description of the education and outreach activities proposed. Examples include such items as involvement of students in the research activities, technology transfer plans, public information programs that will inform the general public of the benefits being gained from the research, and/or plans for incorporation of scientific results obtained into educational curricula consistent with educational standards.

Where appropriate, the supported institution will be required to produce, in collaboration with NASA, a plan for communicating to the public the value and importance of their work. Once NRA selections are made, the selected PIs will have an opportunity to request additional funding through an ESMD-sponsored pilot program to implement an education outreach program at the grades 6-12 level, at an amount not to exceed $10,000 per year for the term of the grant/cooperative agreement. A request for proposal will accompany the selection notification letter. Proposals will be due within 60 days of selection notification and shall be limited to 4 pages. A review of these proposals by educational specialists will determine which proposals will be funded.

F. NASA Safety Policy

Safety is NASA's highest priority. Safety is the freedom from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment. NASA's safety priority is to protect: (1) the public, (2) astronauts and pilots, (3) the NASA workforce (including employees working under NASA instruments), and (4) high-value equipment and property. All research conducted under NASA auspices shall conform to this philosophy.

G. Availability of Funds for Award

Funds are not currently available for awards under this announcement. The Government's obligation to make award(s) is contingent upon the availability of the appropriated funds from which payment can be made and the receipt of proposals that NASA determines are acceptable for award under this announcement.

II. Award Information

The selected proposal will be funded as a research grant / cooperative agreement in one-year increments for activities lasting up to **four years.** The mechanism for funding the successful proposal will be a single grant / cooperative agreement, with funding allocations to participating investigators based on the submitted budget and project review. The funding duration will depend on proposal requirements, review panel recommendations, and continuing progress of the activity. All proposals will be evaluated for overall merit by independent peer review panels, and a second review for NASA relevance and proposed cost by the cognizant NASA program office. NASA reserves the right to "partner" research projects that it determines will augment one another.

The government's obligation to make awards is contingent upon the availability of appropriated funds from which award payments can be made, and the receipt of proposals that the government determines are acceptable for award under this NRA. Depending on available funding and the results of peer review for scientific merit, up to 20 investigations may be selected. It is anticipated that a typical radiobiology award will average **$300,000** per year (total cost), and a typical physics award will average **$150,000** per year (total cost).

Separate funding for direct and indirect costs is not provided: thus the amount of the award requested is the total of all cost submitted in the proposed budget. NASA reserves the right to return proposals, without review, that exceed the described award amounts. NASA does not provide separate funding for direct and indirect costs; thus, the amount of the award requested is the total of all costs submitted in the proposed budget. It is estimated that the initial selection will be announced by **April 2005** and the grant / cooperative agreement awarded in a reasonable timeframe thereafter.

III. Eligibility Information

A. Eligibility of Applicants

All categories of U.S. institutions are eligible to submit proposals in response to this NRA. Principal Investigators may collaborate with universities, Federal Government laboratories, the private sector, and state and local government laboratories. In all such arrangements, the applying entity is expected to be responsible for administering the project according to the management approach presented in the proposal.

The applying entity must have in place a documented base of ongoing high quality research in science and technology, or in those areas of science and engineering clearly relevant to the specific programmatic objectives and research emphases indicated in this Announcement. Present or prior NASA support of research or training in any institution or for any investigator is not a prerequisite to submission of a proposal or a competing factor in the selection process.

B. Cost Sharing or Matching

If an institution of higher education, hospital, or other non-profit organization wants to receive a grant or cooperative agreement from NASA, cost sharing is not required. However, NASA can accept cost sharing if it is voluntarily offered (See the Handbook, Section B, Provision 1260.123, “Cost Sharing or Matching,” which describes the acceptable forms of cost sharing). If a commercial organization wants to receive a grant or cooperative agreement cost sharing is required, unless the commercial organization can demonstrate that they are unlikely to receive substantial compensating benefits for performance of the work. If no substantial compensating benefits are likely to be received, then cost sharing is not required but can be accepted (See the Handbook, Section D, Provision 1274.204, “Costs and Payments”.)

C. Guidelines for International Participation

NASA’s policy welcomes the opportunity to conduct research with non-U.S. organizations on a cooperative, no-exchange-of-funds basis. Although Co-Is or collaborators employed by non-U.S. organizations may be identified as part of a proposal submitted by a U.S. organization, NASA funding may not normally be used to support research efforts by non-U.S. organizations at any level; however, the direct purchase of supplies and/or services that do not constitute research from non-U.S. sources by U.S. award recipients is permitted.

Export Control Guidelines Applicable to Proposals Including Foreign Participation. Proposals and proposals including foreign participation must include a section discussing compliance with U.S. export laws and regulations, e.g., 22 CFR Parts 120-130 and 15 CFR Parts 730-774, as applicable to the circumstances surrounding the particular foreign participation. The discussion must describe in detail the proposed foreign participation and is to include, but not be limited to, whether or not the foreign participation may require the prospective investigator to obtain the prior approval of the Department of State or the Department of Commerce via a technical assistance agreement or an export license, or whether a license exemption/exception may apply. If prior approvals via licenses are necessary, discuss whether the license has been applied for or if not, the projected timing of the application and any implications for the schedule. Information regarding U.S. export regulations is available at http://www.pmdtc.org/and http://www.bis.doc.gov/. Investigators are advised that under U.S. law and regulations, spacecraft and their specifically designed, modified, or configured systems, components, and parts are generally considered "Defense Articles" on the United States Munitions List and are subject to the provisions of the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120-130.

IV. Proposal and Submission Information

A. Source of Application Materials

All information needed to apply to this solicitation is contained in this announcement and in the companion document entitled "2004 Guidebook for Proposers Responding to NASA Research Announcements" (hereafter referred to as the Guidebook for Proposers) that is located at http://www.hq.nasa.gov/office/procurement/nraguidebook/. This solicitation and any modifications or updates to this solicitation are available at: http://research.hq.nasa.gov/code_u/nra/current/ NNH04ZUU005N /index.html.

Except where specifically stated otherwise in this NRA, applicants must prepare proposals in accordance with the Guidebook for Proposers. Proposals that do not conform to the standards outlined in this NRA and included in the Guidebook for Proposers may be declared noncompliant and returned without review. Note that the NASA policy for proposals involving non-U.S. participants is given in Section (l) of Appendix B of this Guidebook. Comments and suggestions of any nature about the Guidebook for Proposers are encouraged and welcomed and may be directed at any time to Mr. Tom Sauret, Office of Procurement, Code HK, NASA Headquarters, 300 E Street SW, Washington, DC 20546-0001; E-mail: Tsauret@mail.hq.nasa.gov.

The following information is specific to this NRA and **supersedes** the information contained in the Guidebook for Proposers.

B. Content and Form of Proposal Submission

1. SYS-EYFUS Registration

SYS-EYFUS is an electronic system used by NASA Headquarters to manage research solicitation activity, plan for the receipt of research proposals, track the receipt and peer evaluation of these proposals, and manage funded research (grants, cooperative agreements, etc.).

The SYS-EYFUS Help Desk is available at (202) 479-9376. Help desk hours are from 8 a.m. to 6 p.m. Eastern time.

All investigators planning to submit a proposal to this solicitation are required to register online with SYS-EYFUS. Comprehensive help, instructions, and contact information are provided online. SYS-EYFUS can be accessed at the following Web address:

http://proposals.hq.nasa.gov/proposal.cfm

If you have previously registered with SYS-EYFUS, you are asked to verify and update your user information. If you have forgotten your user ID or password, select the "Forgot Your Password" option and type in your first and last name to search our database. The system will send an automatic e-mail message with your username and password to the e-mail address listed in our database.

2. Instructions for Preparing and Electronically Submitting a Notice of Intent

All investigators planning to submit a proposal in response to this solicitation are requested to submit a **non-binding** Notice of Intent (NOI) to propose by the due date identified in the Submission Dates and Times Section of this NRA via the Web at the following address:
http://proposals.hq.nasa.gov/proposal.cfm

1) Login to SYS-EYFUS at the URL listed above and select "New Notice of Intent."

2) The Division Specific Opportunities screen will appear. In the selection window, highlight "**UU-OBPR**" and click on "Continue."

3) The List of Existing Opportunities screen will appear. In the selection window, highlight "**Ground-Based Studies for Radiation Biology and Radiation Shielding Materials**" and then click on "Continue."

4) This will bring you to the Notice of Intent Submission Form. **All fields are required.**

    a. The proposal summary should be a succinct and accurate description of the proposed work when read separately from the project description. The summary should contain a brief description stating the specific aims of the proposed work. Describe concisely (300-500 words) the research design and methods for achieving these aims.

b. Please select from **only** the following three options: For the proposal type field on this form, new/no prior support means that the investigator has not received NASA funding from 2001 through 2004, new/prior support means that the investigator has received NASA funding between 2001 through 2004, and revised means that the proposal is a revised version of a proposal submitted to NASA and reviewed from 2001 through 2004, but not funded. A proposal previously submitted but not funded should be identified as being "revised" even if the original Principal Investigator has changed.

c. Indicate the status of IRB/IACUC for your proposal. If IRB or IACUC review is unavoidably delayed beyond the submission of the application, enter "Pending" on the Proposal Cover Page, and be advised that the certification must be received within 90 days after the due date for which the application is submitted.

d. Provide your DUNS and CAGE numbers. If you do not know your DUNS and CAGE numbers, contact your Office of Sponsored Research or equivalent office. All applicants must provide the Dun and Bradstreet (D&B) Data Universal Numbering System (DUNS) number for their organization in the Cover Page of their proposal. This requirement applies to renewals of awards as well as to prospective new awards. The DUNS number is a unique nine-character identification number provided by the commercial company Dun & Bradstreet (D&B). Organizations will use the same DUNS number with every proposal submitted for a Federal grant and cooperative agreement. Note that the DUNS number is site-specific. Applicants may call D&B at 1-866-705-5711 to register and obtain a DUNS number, or access the D&B website at: http://www.dnb.com/us/.

   NASA also requires the applicant's organization to be registered in the Central Contractor Registration (CCR) database and obtain a Commercial And Government Entity (CAGE) code prior to submitting a proposal. The purpose of this requirement is to help centralize information about grant / cooperative agreement recipients and provide a central location for grant / cooperative agreement recipients to change organizational information. Information for registering in the CCR and online documents can be found at http://www.ccr.gov/. Before registering applicants and recipients should review the Central Contractor Registration Handbook, which is also located at http://www.ccr.gov/. The process for obtaining a CAGE code is incorporated into the CCR registration.

5) Click on "Submit NOI Page."

6) The Team Member Page screen will appear, where you can add or remove team members. Select continue if there are no other team members. To add a team member, highlight the role option on the selection list, type in first and last name and click on search. When the resulting set appears, choose the appropriate radio button and click on ADD to add the person to the NOI. After you are done, click on "Continue." **IMPORTANT:** If the team member is not listed in our database, please have them add themselves as a new user to the system. You may then add them to your team member list.

7) After continuing from the Team Members Page, your NOI will be displayed. Click on "Resubmit NOI Page" to complete your NOI submission.

8) You may edit and resubmit your NOI at any time before the submission deadline. Once you submit an NOI, it cannot be deleted, only edited. For title, team member, or any other changes, please edit your existing NOI and resubmit changes to avoid duplicate records.

3. Instructions for Preparing and Electronically Submitting a Proposal Cover Page

All investigators planning to submit a proposal in response to this solicitation must electronically submit proposal cover page information online and provide a hardcopy of the cover page attached to each proposal copy by the due date indicated in the Submission Dates and Times Section of this NRA. The proposal cover page can be submitted and printed via the Web at the following address:

http://proposals.hq.nasa.gov/proposal.cfm

1) Login to SYS-EYFUS at the URL listed above.

2) To submit a New Proposal Cover Page, click the "New Proposal Cover Page" option on the SYS-EYFUS Options screen, and the New Proposals Cover Page screen will appear.

3) If you previously submitted an NOI in response to this solicitation, choose to carry over the existing NOI. This option will populate the cover page fields with the NOI information. Edit the information as necessary, click "Continue," and proceed to #8 below.

4) If you did not previously submit an NOI, click on New Proposal Cover Page option, and the Division Specific Opportunities screen will appear.

5) In the selection window, highlight "**UU-OBPR"** and click on "Continue."

6) The List of Existing Opportunities screen will appear. In the selection window, highlight "**Ground-Based Studies for Radiation Biology and Radiation Shielding Materials"** and then click on "Continue."

7) This will bring you to the Proposal Cover Page Submission Form. Fill in all the fields. All fields are required.

   a. The proposal summary should be a succinct and accurate description of the proposed work when read separately from the project description. The summary should contain a brief description stating the specific aims of the proposed work. Describe concisely (300-500 words) the research design and methods for achieving these aims.

   b. Please select from **only** the following three options: For the proposal type field on this form, <u>new/no prior support</u> means that the investigator has not received NASA funding from 2001 through 2004, <u>new/prior support</u> means that the investigator has received NASA funding between 2001 through 2004, and <u>revised</u> means that the proposal is a revised version of a proposal submitted to NASA and reviewed from 2001 through 2004, but not funded. A proposal previously submitted but not funded should be identified as being "revised" even if the original Principal Investigator has changed.

   c. Indicate the status of IRB/IACUC for your proposal. If IRB or IACUC review is unavoidably delayed beyond the submission of the application, enter "Pending" on the Proposal Cover Page, and be advised that the certification must be received within 90 days after the due date for which the application is submitted.

   d. Provide your DUNS and CAGE numbers. If you do not know your DUNS and CAGE numbers, contact your Office of Sponsored Research or equivalent office. All applicants must provide the Dun and Bradstreet (D&B) Data Universal Numbering System (DUNS) number for their organization in the Cover Page of their proposal. This requirement applies to renewals of awards as well as to prospective new awards. The DUNS number is a unique nine-character identification number provided by the commercial company Dun & Bradstreet (D&B). Organizations will use the same DUNS number with every proposal submitted for a Federal grant and cooperative agreement. Note that the DUNS number is site-specific. Applicants may call D&B at 1-866-705-5711 to register and obtain a DUNS number, or access the D&B website at: http://www.dnb.com/us/.

      NASA also requires the applicant's organization to be registered in the Central Contractor Registration (CCR) database and obtain a Commercial And Government Entity (CAGE) code prior to submitting a proposal. The purpose of this requirement is to help centralize information about grant / cooperative agreement recipients and provide a central location for grant / cooperative agreement recipients to change organizational information. Information for registering in the CCR and online documents can be found at http://www.ccr.gov/. Before registering applicants and recipients should review the Central Contractor

Registration Handbook, which is also located at http://www.ccr.gov/. The process for obtaining a CAGE code is incorporated into the CCR registration.

Click on "Continue."

8) The Team Member Page screen will appear, where you can add or remove team members. Every proposal must specify the critically important personnel who are expected to play a significant role in the execution of the proposed effort and their institution of employment. Categories of personnel to be included as Team Members are described in Guidebook for Proposers.

   You must include your authorizing official as a team member. When you complete and print the proposal cover page, you will see signature blocks both for yourself and your authorizing official. You are required to submit one original signed (by both you and your authorizing official) cover page with your proposal hardcopies.

   IMPORTANT: If the team member is not listed in our database, please have them add themselves as a new user to the system. You may then add them to your team member list.

9) After continuing from the Team Member Page, the Proposal Options Page appears.

10) Please fill out the budget form by clicking on the "Budget" button, filling in project costs, and clicking "Continue." This will bring you to the Proposal Budget Review Page. Click "Continue" if the information is correct.

11) After verifying your budget information, you will be returned to the Proposal Options Page. Click the "Show/Print" button.

12) For detailed budget information, you must use the budget forms provided at http://research.hq.nasa.gov/code_u/nra/current/ NNH04ZUU005N /index.html Sample copies of these forms are also available as attachments to this NRA and must be filled out for each year of grant / cooperative agreement support requested. These forms cannot be electronically submitted. Fill out the forms and attach them to your proposal.

13) At the page entitled Proposal Information Item List, click "Continue" to preview your Proposal Cover Page. Print the cover page from your Internet browser once you have reviewed the information. The cover page must be signed by both the Principal Investigator and the authorizing official and attached to the front of your proposal before submission of hard copies to NASA.

    By signing and submitting the proposal identified on the cover sheet, the authorizing official of the proposing institution (or the individual investigator if there is no proposing institution) 1) certifies that the statements made in the proposal are true and complete to the best of his/her knowledge; 2) agrees to accept the obligations to comply with NASA Award terms and conditions if an award of a grant or cooperative agreement is made as a result of this proposal (does not apply to contract awards); and 3) provides certification to the following that are: (i) Certification Regarding Debarment, Suspension, and Other Responsibility Matters, (ii) Certification Regarding Lobbying, and (iii) Certification of Compliance with the NASA Regulations Pursuant to Nondiscrimination in Federally Assisted Programs.

Once you print your cover page, the electronic portion of your NASA proposal submission is complete.

14) You may edit and resubmit your proposal cover page at any time before the submission deadline as indicated in the Submission Dates and Times Section of this NRA. Please note that once you submit a proposal cover page, it can only be edited, not deleted. For title, team member, budget or any other changes, please edit your existing proposal cover page and resubmit changes to avoid duplicate records. After you print your edited cover page, your changes are automatically submitted to NASA.

4. Instructions for Preparation of Proposals

All proposals submitted must include the completed cover page form as described above. The name of the Principal Investigator should appear in the upper right hand corner of each page of the proposal, except on the cover page form, where fields are provided for this information. Note that the proposal must specify the period of performance for the work described; periods of performance may be up to any duration up to the maximum duration identified in the Announcement section of this NRA but should be suitable for the project proposed.

The proposal must include the following material, in this order:

(1) Proposal Cover Page: Solicited Proposal Application, including certification of compliance with U.S. code (if applicable). One signed original required. Please see "Instructions for Preparing and Electronically Submitting a Proposal Cover Page" in Section IV.B.3 above for instructions on how to complete the proposal cover page information.

(2) Checklist for proposers. This checklist is provided in the forms appendix of this document and can be downloaded from : http://research.hq.nasa.gov/code_u/nra/current/ NNH04ZUU005N /index.html

(3) Transmittal Letter or Prefatory Material, if any (see Guidebook for Proposers).

(4) Proposal Title Page, with Notice of Restriction on Use and Disclosure of Proposal Information, if any (see Guidebook for Proposers).

(5) Project Description: The length of the Project Description section of the proposal cannot exceed 20 pages using regular (12 point) type. Text must be printed on one side only and should have the following margins: left = 1.5”; Right, top, bottom = 1.0”. Referenced figures must be included in the 20 pages of the Project Description. The Bibliography, Management Approach, and all following sections are not considered part of the 20-page project description. Proposals that exceed the 20-page limit for the project description will not be reviewed. The proposal should contain sufficient detail to enable reviewers to make informed judgments about the overall merit of the proposed research and about the probability that the investigators will be able to accomplish their stated objectives with current resources and the resources requested. In addition, the proposal should clearly indicate the relationship between the proposed work and the research emphases defined in this Announcement. Reviewers are not required to consider information presented as appendices or to view and/or consider Web links in their evaluation of the proposal.

(6) Management Approach: Each proposal must specify a single Principal Investigator who is responsible for carrying out the proposed project and coordinating the work of other personnel involved in the project. In proposals that designate several senior professionals as key participants in the research project, the management approach section should define the roles and responsibilities of each participant and note the proportion of each individual’s time to be devoted to the proposed research activity. The proposal must clearly and unambiguously state whether these key personnel have reviewed the proposal and endorsed their participation.

Investigators are strongly encouraged to identify only the most critically important personnel to aid in the execution of their proposals. Should such positions be necessary, Co-Investigators (co-Is) may be identified who are critical for the successful completion of research through the contribution of unique expertise and/or capabilities, and who serve under the direction of the PI, regardless of whether or not they receive compensation under the award. Most NRAs require a co-I to have a well-defined role in the research that is defined in the Management section of the proposal. Evidence of a co-I’s commitment to participate is often requested through a brief letter to be included with the proposal.

There are three subcategories of co-Is that a proposal may identify, as appropriate:

- A co-I may be designated as the *Science PI* for those cases where the proposing institution does not permit that individual to formally serve as the PI as defined above. In such a case, the Science PI will be understood by NASA to be in charge of the scientific direction of the proposed work, although the formally designated PI is still held responsible for the overall direction of the effort and use of funds.

- A co-I may be designated as an *Institutional PI* when their institution is making a major contribution to a proposal submitted by a PI from another institution.

- A co-I from a non-U.S. institution may be designated as a *co-Principal Investigator* (co-PI) should such a designation serve required administrative purposes in that co-I's institution and/or for the procurement of funding by that co-I from their sponsoring funding authority.

Additional category positions are often included in proposals as defined as follows:

- *A Postdoctoral Associate* holds a Ph.D. or equivalent degree and is identified as a major participant in the execution of the proposed research. Such personnel may be identified by name or only by function in those cases where their recruitment depends on the successful selection of the proposal.
- *Other Professional* is a description appropriate for personnel who support a proposal in a critical albeit intermittent manner, such as a consulting staff scientist or a key Project Engineer and/or Manager, who is not identified as a co-I or Postdoctoral Associate.
- A *Graduate Student* included in a proposal is working for a post-graduate degree and will support the proposed research under direction of the PI. Such a student may be identified by name or only by function in case their recruitment depends on the successful selection of the proposal.
- A C*ollaborator* is an unfunded position included in a proposal, whose participation is less critical than a co-I, but who is committed to provide a specific contribution to the proposal

(7) The investigator must examine and understand the Bioastronautics Critical Path Roadmap (BCPR), and specify in their proposal the rationale and evidence underlying which risks and critical questions their proposed research will answer http://research.hq.nasa.gov/code_u/bcpr/index.cfm. NASA will perform an assessment to understand how the proposed research addresses the BCPR risks and critical questions. Proposals that do not identify what BCPR risks and questions are being addressed by the research will be returned to the investigator without review.

(8) Personnel/Biographical Sketches: The biographical sketch for each investigator should not exceed two pages. If the list of qualifications and publications exceeds two pages, select the most pertinent information. List, in chronological order, the titles, all authors, and complete references to all publications pertinent to this application (see Guidebook for Proposers.) A sample biographical sketch form can be downloaded at http://research.hq.nasa.gov/code_u/nra/current/ NNH04ZUU005N /index.html. A sample copy of the form is available as an attachment to this NRA. These forms cannot be electronically submitted. Omit social security numbers and other personal items that do not merit consideration in evaluation of the proposal. Provide similar biographical information on other senior professional personnel who will be directly associated with the project. Provide the names and titles of any other scientists and technical personnel associated substantially with the project in an advisory capacity. Universities should list the approximate number of students or other assistants, with information as to their level

of academic attainment. Any special industry-university cooperative arrangements should be described. Fill out the forms and attach them to your proposal

(9) Facilities and Equipment: Describe the available facilities and major items of equipment specially adapted or suited to the proposed research activities, and any additional major equipment that will be required. Identify any government-owned facilities, industrial plant equipment, or special tooling that are proposed for use in the research activities.. The research plan must provide evidence that such facilities or equipment will be made available if the proposal is accepted. Before requesting a major item of capital equipment, the proposer should determine the availability of equipment already within the organization as an alternative to purchase. Where such arrangements cannot be made, the proposal should state this explicitly. The need for items that can be typically used for research and non-research purposes should be explained.

(10) Special Matters (specific information on animal or human subjects protocol approval required, if applicable)

For proposals employing human subjects and/or animals, assurance of compliance with human subjects and/or animal care and use provisions is required on the Proposal Cover Page. In addition, the application must include a statement from the applicant institution certifying that the proposed work will meet all Federal and local human subjects requirements and/or animal care and use requirements.

Policies for the protection of human subjects in NASA sponsored research projects are described in NASA Management Instruction (NMI) 7100.8B (*Protection of Human Research Subjects*). Animal use and care requirements are described in the NASA Code of Federal Regulations (CFR) 1232 (*Care and Use of Animals in the Conduct of NASA Activities*). Both documents are available from the Office of Biological and Physical Research, Code UB, NASA Headquarters, Washington, DC 20546.

Additional Requirements for Research Employing Human Subjects

A letter signed by the Chair of the Institutional Review Board (IRB) identifying the proposal submitted to NASA by title and certifying approval of proposed human subjects protocols and procedures should be included with each copy of the proposal. IRB certifications for other research proposals or grants / cooperative agreements cannot be substituted (even if they employ the same protocols and procedures).

If IRB certification is pending on the proposal due date, select “pending” from the IRB/IACUC section menu on the Proposal Cover Page, and include with each copy of the proposal a letter signed by the IRB Chair identifying the proposal by title and indicating the status of the IRB review process at the time of submission. IRB certification must be received no later than 90 days after the proposal due date. An application lacking the required IRB certification 90 days after the proposal due date will be considered incomplete and may be returned to the applicant without review.

NASA will require current IRB certification prior to each year's award.

Additional Requirements for Research Employing Animals

Specific information describing and justifying the use of animal subjects must be included in the proposal.

A letter signed by the Chair of the Institutional Animal Care and Use Committee (IACUC) identifying the proposal submitted to NASA by title and certifying approval of the proposed animal research protocols and procedures should be included with each copy of the proposal. The institution's Public Health Service Animal Welfare Assurance Number must be included on the IACUC certification and entered in the IRB/IACUC section of the Proposal Cover Page. IACUC certifications for other research proposals or grants / cooperative agreements cannot be substituted (even if they employ the same protocols and procedures).

If IACUC certification is pending on the proposal due date, select "pending" from the IRB/IACUC selection menu on the Proposal Cover Page, and include with each copy of the proposal a letter signed by the IACUC Chair identifying the proposal by title and indicating the status of the IACUC review process at the time of submission. IACUC certification must be received no later than 90 days after the proposal due date. An application lacking the required IACUC certification 90 days after the proposal due date will be considered incomplete and may be returned to the applicant without review. NASA will require current IACUC certification prior to each year's award.

(11)Detailed Budget and Supporting Budgetary Information

For detailed budget information, you must use the forms provided at http://research.hq.nasa.gov/code_u/nra/current/ NNH04ZUU005N /index.html. Sample copies of these forms are also available as attachments to this NRA. These forms cannot be electronically submitted. Fill out the forms and attach them to your proposal.

NASA is expected to be operating on the basis of full cost accounting as soon as possible, including all Civil Service salaries with overhead. In the interim period, proposals should use the accounting method authorized at their institutions at the time proposals are due and for the entire proposed period of performance. Funds to support the Resident Research Assistant (RRA) Postdoctoral Program costs (e.g., stipend, travel, computer time, supplies, etc.) are to be budgeted within the NASA intramural Principal Investigator budget.

If travel is planned, the proposal budget should include appropriate travel funds for visits to NASA field centers (as appropriate) and presentation of findings at professional society meetings.

In this solicitation, the terms "cost" and "budget" are used synonymously. Sufficient proposal cost detail and supporting information are required; funding amounts proposed with no explanation (e.g., Equipment: $1,000, or Labor: $6,000) may cause delays in evaluation and award. Generally, costs will be evaluated for realism, reasonableness, allowability, and allocation. The budgetary forms define the desired detail, but each category should be explained. Offerors should exercise prudent judgment in determining what to include in the proposal, as the amount of detail necessarily varies with the complexity of the proposal.

The following examples indicate the suggested method of preparing a cost breakdown:

<u>Direct Labor</u>

Labor costs should be segregated by titles or disciplines with estimated hours and rates for each. Estimates should include a basis of estimate, such as currently paid rates or outstanding offers to prospective employees. This format allows the Government to assess cost reasonableness by various means including comparison to similar skills at other organizations.

<u>Other Direct Costs</u>

Please detail, explain, and substantiate other significant cost categories as described below:

- <u>Subcontracts</u>: Describe the work to be contracted, estimated amount, recipient (if known), and the reason for subcontracting.
- <u>Consultants</u>: Identify consultants to be used, why they are necessary, the time they will spend on the project, and the rates of pay.
- <u>Equipment</u>: List separately. Explain the need for items costing more than $5,000. Describe basis for estimated cost. General-purpose equipment is not allowable as a direct cost unless specifically approved by the NASA Grant / Cooperative agreement Officer. Any equipment purchase requested as a direct charge must include the equipment description, how it will be used in the conduct of the basic research proposed, and why it cannot be purchased with indirect funds.
- <u>Supplies</u>: Provide general categories of needed supplies, the method of acquisition, and estimated cost.
- <u>Travel</u>: Describe the purpose of the proposed travel in relation to the grant / cooperative agreement, and provide the basis of estimate, including information on destination and number of travelers (if known). **Note: Investigators are required to include travel to an annual PI meeting in their budget.**
- <u>Other</u>: Enter the total of direct costs not covered by a) through e). Attach an itemized list explaining the need for each item and the basis for the estimate.

Indirect Costs

Indirect costs should be explained to an extent that will allow the Government to understand the basis for the estimate. Examples of prior year historical rates, current variances from those rates, or an explanation of other basis of estimates should be included. Where costs are based on allocation percentages or dollar rates, an explanation of rate and application base relationships should be given. For example, the base to which the General and Administrative (G&A) rate is applied could be explained as: application base equals total costs before G&A less subcontracts.

All awards made as a result of this NRA maybe funded as grants or cooperative agreements. However, while proposals submitted by "for profit" organizations are allowed, they cannot include a "fee."

(12) Other Support: You must provide information on other support for specific sources of other support for the principal investigator and each Co-Investigator (not consultants). A sample form is provided at: http://research.hq.nasa.gov/code_u/nra/current/ NNH04ZUU005N /index.html. A sample copy of the form is also available as attachment to this NRA

(13) Appendices, if any (**reviewers are not required to consider information presented in appendices**).

C. Submission Dates and Times

One (1) signed original cover page and proposal and twenty (20) copies of the proposal cover page and proposal **must be received by 4:30 p.m. Eastern Time, November 19, 2004.** Proposals shall not be submitted electronically, except for parts specified in this NRA. Proposals mailed through the U.S. Postal Service by express, first class, registered, or certified mail are to be sent to the following address:

NASA Peer Review Services
SUBJECT: **2004 Radiation NRA**
500 E Street SW
Suite 200
Washington, DC 20024

Proposals that are hand delivered or sent by commercial delivery or courier services are to be delivered to the above address between 8:00 a.m. and 4:30 p.m. Proposals must be received by 4:30 p.m. Eastern time on the proposal due date. The telephone number (202) 479-9030 may be used when required for reference by delivery services. NASA Peer Review Services (NPRS) cannot receive deliveries on Saturdays, Sundays, or federal holidays. NPRS will send notification to the investigator confirming proposal receipt within 5 business days of the proposal receipt date; however, there will not be a response from the Office of Biological and Physical Research.

The following items apply only to this Announcement:

Solicitation Announcement Identifier:	**NRA** NNH04ZUU005N
Number of Copies Required:	**Original + 20 copies**
Proposals Due:	**November 19, 2004**
Estimated Selection Announcement:	**April 2005**
Selecting Officials:	**TBD**

D. Funding Restrictions

- The construction of facilities is not an allowed activity unless specifically stated so in the program description. For further information on the allowability of costs, refer to the cost principles cited in the Guidebook for Proposers.
- Travel, including foreign travel, is allowed as may be necessary for the meaningful completion of the proposed investigation, as well as for publicizing its results at an appropriate professional meeting.
- U.S. research award recipients may directly purchase of supplies and/or services that do not constitute research from non-U.S. sources, but award funds may not be used to fund research carried out by non-U.S. organizations. However, subject to possible export control restrictions, foreign nationals may conduct research while employed by a U.S. organization.
- Profit for commercial organizations is allowed under contract awards only.
- NASA does not provide separate funding for direct and indirect costs; thus, the amount of the award requested is the total of all costs submitted in the proposed budget.
- Regardless of whether functioning as a team lead or as a team member, personnel from NASA Centers must propose budgets based on Full Cost Accounting (FCA). Non-NASA U.S. Government organizations should propose based on FCA unless no such standards are in effect; in that case such proposers should follow the Managerial Cost Accounting Standards for the Federal Government as recommended by the Federal Accounting Standards Advisory Board. For further information, see http://www.hq.nasa.gov/fullcost/.

V.Proposal Review Information

The following information is specific to this NRA and **supersedes** the information contained in the Guidebook for Proposers.

A. Intrinsic Scientific or Technical Merit Review and Evaluation Criteria

The overall evaluation process for proposals submitted in response to this Announcement will include review of relevance, cost criteria, and merit criteria. All of the following criteria will be used in determining the merit score (approach is the most important; investigation is given more weight than significance, innovation, and environment):

- **Significance:** Does this study address an important problem? If the aims of the application are achieved, how will scientific knowledge or technology be advanced? What will be the effect of these studies on the concepts, methods, or products that drive this field? Is there a significant societal or economic impact?
- **Approach:** Are the conceptual framework, design, methods, and analyses adequately developed, well integrated, and appropriate to the aims of the project? Is the proposed approach likely to yield the desired results? Does the applicant acknowledge potential problem areas and consider alternative tactics?
- **Innovation:** Does the project employ appropriate novel concepts, approaches, or methods? Are the aims original and innovative? Does the project challenge existing paradigms or develop new methodologies or technologies?
- **Investigator:** Is the investigator appropriately trained and well suited to carry out this work? Is the work proposed appropriate to the experience level of the principal investigator and any co-investigators? Is the evidence of the investigator's productivity satisfactory?
- **Environment:** Does the scientific environment in which the work will be performed contribute to the probability of success? Do the proposed experiments take advantage of unique features of the scientific environment or employ useful collaborative arrangements? Is there evidence of institutional support?

B. Review and Selection Process

1. Compliance Matrix

All proposals must comply with the general requirements of the Announcement as described in both this solicitation and the Guidebook for Proposers. Upon receipt, proposals will be reviewed for compliance with these requirements including:

1. Submission of complete proposals specified in this Announcement. Proposals must be responsive to the areas of program element emphasis described in this Announcement and include a project description that is not more than 20 pages in length.
2. Submission of appropriate Institutional Review Board (IRB) or Animal Care and Use Committee (ACUC) certification for all proposals using human or animal test subjects.
3. Submission of a budget that is within the guidelines specified in this Announcement and is for a funding period not exceeding that described in the Announcement.
4. Proposals that are revised versions of proposals previously submitted to NASA must be clearly designated as such on the proposal cover page and must contain an explanation of how the revised proposal has addressed criticisms from previous NASA review. This explanation should be presented at the beginning of the project description in a separate section of no more than two pages, and is in addition to the 20 pages allowed for the project description. Related changes to the research plan should be highlighted in the body of the project description.

5. Submission of Gender and Minority inclusion data as appropriate for the proposed research.
6. Submission of all other appropriate information as required by this Announcement.

Note: At NASA's discretion, non-compliant proposals may be withdrawn from the review process and returned to the investigator without further review.

Compliant proposals submitted in response to this Announcement will undergo an intrinsic scientific or technical merit review. Only those proposals most highly rated in the merit review process will undergo additional reviews for program relevance and cost.

2. **Review and Selection**

The overall evaluation process for proposals submitted in response to this Announcement will include the following reviews:

First Tier Merit Review: A review for intrinsic technical or scientific merit and overall impact will be conducted for all proposals.

Second Tier Review for Relevance and Cost: Relevance to NASA, program balance and proposed project cost.

The **first review tier** will be a merit review by a panel of scientific or technical experts.. The number and diversity of experts required will be determined by the response to this NRA and by the variety of disciplines represented in the proposals relevant to the research emphases described in Appendix A. The merit review panel will assign ***a score from 0-100*** based upon the intrinsic scientific or technical merit of the proposal. This score will reflect the consensus of the panel.

The score assigned by this panel ***will not be affected by the cost of the proposed work nor will it reflect the programmatic relevance of the proposed work to NASA***.. The panel will be asked to include in their critique of each proposal any comments they may have concerning the proposal's budget and relevance to NASA.

The **second review** will evaluate the programmatic relevance, balance and cost of all proposed work. This review will be conducted by NASA Program Scientists and Managers. Evaluation of the cost of a proposed effort includes consideration of the realism and reasonableness of the proposed cost and the relationship of the proposed cost to available funds. Programmatic relevance will include an evaluation of how the proposed work may help achieve an appropriate balance of scientific and technical tasks required by critical research issues faced by NASA and ESMD.

In order to optimize resources, NASA is pursuing the intentional formation of investigator partnerships between individual investigators whose experiments will leverage resources by addressing different facets of the same critical question. NASA anticipates that such intentional teaming arrangements will result in better utilization of available resources to resolve specific critical questions. NASA strongly encourages individual investigators submitting applications in response to this NRA to consider identifying collaborations between individual investigators as part of the development of their individual proposals and to identify this pre-coordination in their management plan.

The information resulting from these two levels of review, as described above, will be used to prepare a **selection recommendation** developed by NASA program scientists and managers for each of the program elements described in this Announcement. This recommendation will be based on:

1. The scientific or technical merit review score from the peer review panel.
2. The programmatic relevance.
3. The cost of each proposal.

This **selection recommendation** is the responsibility of the NASA program scientist(s). Selection for funding will be made by the selecting official identified in the Submission Dates and Times Section of this NRA. There will be one selection.

VI. Award Administration Information

A. Award Notices

At the end of the selection process, each proposing organization is notified of its selection or nonselection status. NASA provides debriefings to those investigators who request one. The selection letters will include a statement indicating the selected organization's business office will be contacted by a NASA Contracting or Grant / Cooperative agreement Officer, who is the only official authorized to obligate the Government, and a reminder that any costs incurred by the investigator in anticipation of an award are at their own risk. Selection notification will be made by a letter signed by the selecting official.

The NASA Procurement Office will determine the type of award instrument, request further business data, negotiate the resultant action, and are the only personnel with the authority to obligate government funds.

NASA reserves the right to offer selection of only a portion of a proposal. In these instances, the investigator will be given the opportunity to accept or decline the offer.

B. Administrative and National Policy Requirements

This solicitation does not invoke any special administrative or National policy requirements, nor do the award(s) that will be made involve any special terms and conditions that differ from NASA's general terms and conditions as given in the Guidebook for Proposers.

C. Program Reporting/Individual Researcher Reporting

It is expected that results from funded research will be submitted to peer-reviewed journals as the work progresses. Only published papers that acknowledge NASA's support and identify the grant or cooperative agreement will be counted as resulting from the research project and used to evaluate its productivity.

Annual Reporting. The Office of Biological and Physical Research publishes a comprehensive online document titled OBPR Program Tasks and Bibliography (Task Book) which includes descriptions of all current peer-reviewed activities funded by the division. Since its inception, the Task Book has served as an invaluable source of information for NASA as well as the scientific and technical communities.

Investigators are required to provide NASA with this summary information at a minimum of once per year. This information will be made available to the scientific community and will be used to assess the strength of the Division's programs. It will also serve as the basis for determining the degree of progress of the project. The information provided for the Task Book will meet both the requirements for program annual reporting requirements and the individual researcher task book reporting. Updates can be made throughout the duration of the project at anytime during the year, with a due date of at least once per year 60 days prior to the anniversary date of the grant / cooperative agreement start date.

The information requested will include:

- an abstract,
- a brief statement of progress during,
- a brief statement of benefits of the research with respect to life on Earth,
- an updated bibliographic list,
- a copy or reprint of each publication listed in the bibliography,
- a listing of presentations or activities conducted at 6-12 educational institutions,
- a listing of interactions, presentations, or other activities with the general public, and
- a statement of potential scientific, technological, economic or societal impact.

Note that although this publication will be made available to the general scientific community, it is not a substitute for traditional scientific reporting in journals and elsewhere.

All articles submitted for publication must include the following statement: "This research was funded in whole or in part by a grant / cooperative agreement from the Exploration Systems Mission Directorate of the National Aeronautics and Space Administration." Publications not including this acknowledgement will not be considered to be the product of NASA-funded research when NASA assesses the progress of the grant / cooperative agreement.

Final Report. A final report must be provided to the appropriate Division Director at NASA HQ at the end of the funding period, including a detailed listing of all peer-reviewed publications. Information required for inclusion in final reports is:

- summary of the research activities;
- statement of the specific objectives;
- significance of the work;
- background;
- overall progress during the performance period;
- narrative discussion of technical approaches including problems encountered;
- accomplishments related to approach; and
- an appendix with bibliography and copies of all publications and reports. Any publications or other public materials containing data are particularly important to include in this section.

VII. NASA Contacts

Additional technical information for the NASA programs is available from

Walter Schimmerling, Ph.D.
NASA Headquarters
Washington, DC 20546-0001
Telephone: (202) 385-2205
Fax: (202) 358-4168
E-mail: wschimme@hq.nasa.gov

Mike Wargo, Ph.D.
NASA Headquarters
Washington, DC 20546-0001
Telephone: (202) 385-0822
Fax: (202) 358-3091
E-mail: mwargo@hq.nasa.gov

The contracting point of contact will be specified in each selection notification letter.

Potential investigators should read with care the program descriptions that are of interest and focus their proposals on the specific research emphases defined in this Announcement.

Your interest and cooperation in participating in this effort is appreciated.

VIII. References

A. General References

Guidebook For Proposers Responding To A NASA Research Announcement (NRA) is available online at the following address:
http://www.hq.nasa.gov/office/procurement/nraguidebook/proposer2003.pdf

OBPR Program Tasks and Bibliography (Task Book) for **FY 1995 through FY 2002** are available online at the following address:
http://research.hq.nasa.gov/taskbook.cfm

Space Life Sciences Ground Facilities Information Package. This document is available online at the following address:
http://research.hq.nasa.gov/code_u/nra/current/NRA-03-OBPR-03/index.html

National Academy of Science. National Research Council Committee on Space Biology and Medicine. Mary J. Osborn, Committee Chairperson. **A Strategy for Research in Space Biology and Medicine in the New Century.** 1998. Washington D.C: National Academy Press. Web address: http://www.nas.edu/ssb/csbm1.html

A Nicogossian, C Huntoon, and S Pool. (Eds.) **Space Physiology and Medicine, 3rd ed**. Lea & Febiger. Philadelphia, PA (1994).

FASEB Journal, Vol. 13, Supplement, **Cell & Molecular Biology Research in Space**. (1999).
Brain Research Reviews, **Space Neuroscience Research**. Volume 28, Numbers 1/2, Special Issue, (1998).

NASA Space Radiation Health Program Strategic Plan:
http://spaceresearch.nasa.gov/docs/radiation_strat_plan_1998.pdf

Space Radiation Health Project at Johnson Space Center: http://srhp.jsc.nasa.gov/

B. Selected Radiation References

Alpen, EL, P Powers-Risius, SB Curtis, and R DeGuzman. Tumorigenic potential of high-Z, high-LET charged particle irradiations. *Radiat. Res*. **88**, 132-143 (1993).

Blakely, EA, KA Bjornstad, PY Chang, MP McNamara, E Chang, G Aragon, SP Lin, G Lui, and JR Polansky. Growth and differentiation of human lens epithelial cells in vitro on matrix. *Inv. Opth. & Vis. Sci*. **41**, 3898-3907 (1999).

Cucinotta, FA, W Schimmerling, JW Wilson, LE Peterson, G Badhwar, P Saganti, and J Dicello. Space Radiation Cancer Risks and Uncertainties for Mars Missions. *Radiat. Res*. **156**: (2001)156, 682–688.

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Cucinotta, FA, JW Wilson, JR Williams, and JF Dicello. Analysis of Mir-18 results for physical and biological dosimetry: radiation shielding effectiveness in *LEO. Radiat. Meas*. **31,** 181-191 (2000).

Ernhart, EJ, EL Gillette, and MH Barcellos-Hoff. Immunohistochemical evidence for rapid extracellular matrix remodeling after iron-particle irradiation of mouse mammary gland. *Radiat. Res.* **145**, 157-162 (1996).

Fry RJM, P Powers-Risius, EL Alpen, and EJ Ainsworth. High LET radiation carcinogenesis. *Radiat. Res.* **104**, S188-195 (1985).

Goodhead, DT. Initial events in the cellular effects of ionizing radiations: clustered damage in DNA. *Int. J. Radiat. Biol.* **65**, 7-17 (1994).

Joseph, JA, WA Hunt, BM Rabin, and TK Dalton. Possible accelerated aging induced by 56Fe heavy particle irradiation: Implications for manned space flights. *Radiat. Res.* **130**, 88-93 (1992).

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National Research Council. Radiation Hazards to Crews of Interplanetary Missions: Biological Issues and Research Strategies. National Academy Press, Washington, DC (1996)

National Research Council. Radiation and the International Space Station. National Academy Press, Washington, DC (2000).

Schimmerling, W. Space and radiation protection: scientific requirements for space research. *Radiat. Environ. Biophys.* **34**: 133-137 (1995).

Shimizu, Y, DA Pierce, DL Preston, and K Mabuchi. Studies of the mortality of atomic bomb survivors. Report 12, Part II. Noncancer mortality: 1950-1990. *Radiat. Res.* **152**, 374-389(1999).

Yamada, M, FL Wong, S Fujiwara, M Akahoshi, and G Suzuki. Noncancer disease incidence in atomic bomb survivors, 1958-1998. *Radiat. Res.* **161:** 622-632 (2004).

Zeitlin, C, J Miller, L Heilbronn, K Frankel, W Gong and W Schimmerling, The Fragmentation of 510 MeV/Nucleon Iron-56 in Polyethylene. I. Fragment Fluence Spectra. *Radiat. Res.* **145**: 655-665 (1996).

Zeitlin, C, L Heilbronn, J Miller W Schimmerling, L W Townsend, RK Tripathi, and J Wilson The Fragmentation of 510 MeV/Nucleon Iron-56 in Polyethylene. II. Comparisons between Data and a Model. *Radiat. Res.* **145**: 666-672 (1996).

C. Selected Workshop Reports

Modeling Human Risk: Cell & Molecular Biology in Context.. June, 1997. Ernest Orlando Lawrence Berkeley National Laboratory Report LBNL-40278. Berkeley, CA

International Space Life Sciences Working Group on Radiation Biology. Banff, Canada, November 1997. Mutation Res., 430: No. 2 (1999)

Models for Evaluation of Radiation Risk Factors. Radiat. Res. 156: Number 5, Part 2. November, 2001.

Second International Workshop on Space Radiation Research and13th Annual NASA Space Radiation Health Investigators' Workshop, March 10-15, 2002, Nara, Japan: http://www.nirs.go.jp/usr/workshop/index.htm

D. Selected Radiation Web Sites

Loma Linda University/NASA Radiobiology Program: http://www.llu.edu/llu/ci/nasa/

NASA activities at Brookhaven National Laboratory: http://www.bnl.gov/medical/NASA/NASA-home frame.htm

NASA Specialized Center of Research and Training at Lawrence Berkeley Laboratory: http://www.lbl.gov/lifesciences/NSCORT/

IX. Additional Forms and Proposal Submission Frequently Asked Questions (FAQs)

A. Frequently Asked Questions (FAQs)

The information provided here is in response to questions from investigators such as yourself. Additional information regarding submission procedures and requirements can be found in the research announcement to which you are responding, and at the NASA online proposal site:

http://proposals.hq.nasa.gov/proposal.cfm

1. What forms should I use when submitting a proposal?

Currently, the NASA proposal site does not support the uploading of information or forms other than the information gathered while completing the online cover page. Please complete the online cover page early in the process (you can always return and edit the cover page at any time up to the due date). After completing the cover page, any additional information you are required to provide or wish to provide can be submitted in hardcopy in any format you choose.

Please find included in this document several sample forms that you may use when providing additional information. A standard checklist of materials to include is also provided. Information outside of the online proposal cover page can be provided in any format you choose, as long as it adheres to the NRA requirements. Please reference the NRA for information on all material required when submitting your proposal. Please be aware that we ask for copies of the completed proposal package, not just the project description, and must **receive** the copies by the proposal due date. The additional information requested in the NRA does not count towards the 20 page limit of your project description.

2. Where does my authorizing official sign?

You must include your authorizing official as a team member. When you complete and print the proposal cover page, you will see signature blocks both for yourself and your authorizing official. You are required to submit one original signed (by both you and your authorizing official) cover page with your proposal hardcopies. To be added as a team member to your proposal, the individual must be registered with the SYS-EYFUS system. If you try and add a team member and they are not found in the database, you must contact and have that individual register as a new SYS-EYFUS user. You will then be able to add them as a team member.

3. Who should I contact if I receive errors or have additional problems while using the NASA proposal site?

For technical support, please e-mail proposals@hq.nasa.gov or call 202-479-9376 (Monday to Friday 8 a.m.- 5 p.m. EST/EDT).

X.Checklist for Proposers and Additional Forms

Form A

CHECKLIST FOR PROPOSERS

(Independent Investigator Research Projects Only)

Proposal Cover Page (completed online)

Checklist for Proposers (Form A)

Proposal Title Page

Response to previous reviews (if applicable, these 2 pages are not included in the 20 page proposal page limit)

Project Description

Bioastronautics Critical Path Roadmap (BCPR) Form (Form B)

Biographical Sketches (Form C)

Facilities and Equipment Description

IRB or ACUC letter/form (if applicable)

Targeted/Planned Enrollment (FOR HUMAN SUBJECTS ONLY, Form D)

Summary Budget Form/Budget Justification (Form E)

Detailed 12-Month Budget (for each year of support, Form F)

Other Support (Form G)

Letters of Collaboration/Support (if applicable)

Appendices, if any

Form B

BIOASTRONAUTICS CRITICAL PATH ROADMAP (BCPR) FORM

(Independent Investigator Research Projects and NSBRI Team Research Projects)

Hypotheses	Risk Number **(from BCPR)**	Bioastronautics Critical Question Number **(from BCPR)**	Enabling Question **(from BCPR)**	Specific Aim

Form C

BIOGRAPHICAL SKETCH
Provide the following information for the key personnel. Photocopy this page or follow this format for each person.

NAME	POSITION TITLE

EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training).

INSTITUTION(S) AND LOCATION	DEGREE(S) (if applicable)	YEAR(S)	FIELD(S) OF STUDY

RESEARCH AND PROFESSIONAL EXPERIENCE: Concluding with present position, list, in chronological order, previous employment, experience, and honors. Include present membership on any Federal Government public advisory committee. List, in chronological order, the titles, all authors, and complete references to all publications during the past three years, and to representative earlier publications pertinent to this application. If the list of publications in the last three years exceeds two pages, select the most pertinent publications. **DO NOT EXCEED TWO PAGES.**

Form D

TARGETED/PLANNED ENROLLMENT FORM

for human subjects only

Principal Investigator/Program Director (Last, First, Middle):

This report format should NOT be used for data collection from study participants.

Study Title: ______________________________

Total Planned Enrollment: ______________________________

TARGETED/PLANNED ENROLLMENT: Number of Subjects			
Ethnic Category	**Sex/Gender**		
	Females	Males	Total
Hispanic or Latino			
Not Hispanic or Latino			
Ethnic Category: Total of All Subjects *			
Racial Categories			
American Indian/Alaska Native			
Asian			
Native Hawaiian or Other Pacific Islander			
Black or African American			
White			
Racial Categories: Total of All Subjects *			

* The "Ethnic Category: Total of All Subjects" must be equal to the "Racial Categories: Total of All Subjects."

Form E

(Independent Investigator Research Projects Only)

BUDGET FOR ENTIRE PROJECT PERIOD
DIRECT COSTS ONLY

BUDGET CATEGORY TOTALS		*1st BUDGET PERIOD*	*ADDITIONAL YEARS OF SUPPORT REQUESTED*		
			2nd	3rd	4th
PERSONNEL (Salary and Fringe Benefits) (Applicant organization only)					
SUBCONTRACTS					
CONSULTANT COSTS					
EQUIPMENT					
SUPPLIES					
TRAVEL	DOMESTIC				
	NON-DOMESTIC				
OTHER EXPENSES					
TOTAL DIRECT COSTS FOR EACH PERIOD					
TOTAL INDIRECT COSTS FOR EACH PERIOD					
TOTAL DIRECT + INDIRECT COSTS FOR EACH PERIOD					
TOTAL DIRECT + INDIRECT COSTS FOR ENTIRE PROJECT					

Form F

JUSTIFICATION FOR UNUSUAL EXPENSES:

(Independent Investigator Research Projects Only)

DETAILED BUDGET FOR 12-MONTH BUDGET PERIOD **DIRECT COSTS ONLY**			FROM		THROUGH
Duplicate this form for each year of research support requested		FUNDING AMOUNT REQUESTED			
PERSONNEL (Applicant Organization Only)					
NAME	**ROLE IN PROJECT**	**EFFORT ON PROJECT**	**SALARY**	**FRINGE BENEFITS**	**TOTALS**
	Principal Investigator				
SUBTOTALS →					
SUBCONTRACTS					
CONSULTANT COSTS					
EQUIPMENT (Itemize; use additional sheet if needed)					
SUPPLIES (Itemize by category; use additional sheet if needed)					
TRAVEL	DOMESTIC				
	NON-DOMESTIC				
OTHER EXPENSES (Itemize by category; use additional sheet if needed)					
TOTAL DIRECT COSTS FOR FIRST 12-MONTH BUDGET PERIOD					
INDIRECT COSTS FOR FIRST 12-MONTH BUDGET PERIOD					
TOTAL COST FOR FIRST 12-MONTH BUDGET PERIOD					

Form G

OTHER SUPPORT

(Independent Investigator Research Projects Only)

Please provide information regarding specific sources of other support for the principal investigator and each co-investigator (not consultants). This information should be provided separately for each individual in the format shown below. List all active support for an individual before listing pending support. Include the investigator's name at the top of each page and number pages consecutively.

<table>
<tr><td colspan="3">NAME OF INDIVIDUAL
ACTIVE/PENDING</td></tr>
<tr><td>Project Number (Principal Investigator)</td><td>Dates of Approved/
Proposed Project</td><td>Percent Effort</td></tr>
<tr><td>Source</td><td colspan="2">Annual Direct Costs</td></tr>
<tr><td colspan="3">Title of Project (or Subproject)</td></tr>
<tr><td colspan="3">One-sentence description of project goals. (The major goals of this project are…)</td></tr>
<tr><td colspan="3">Brief description of potential scientific or commitment overlap with respect to this individual between this application and projects described above (summarized for each individual).</td></tr>
</table>